Proposal for a

LARP Schottky task

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Why Schottky (Why instrumentation)?

- The LHC will undoubtedly encounter numerous problems during commissioning and early running. Many are foreseen, some may well be surprises.
- Having proper instrumentation there from the start will certainly help diagnose these issues and reach higher luminosity, faster.

Observables

- Average & bunch-by-bunch
  - Tunes
  - Momentum spread
  - Emittance
  - Chromaticity

- Useful for
  - Beam-bean
  - PACMAN
  - E-cloud
  - …
- Also useful for
  - Cavity phasing
  - …

Bunch-by-bunch tune in LHC

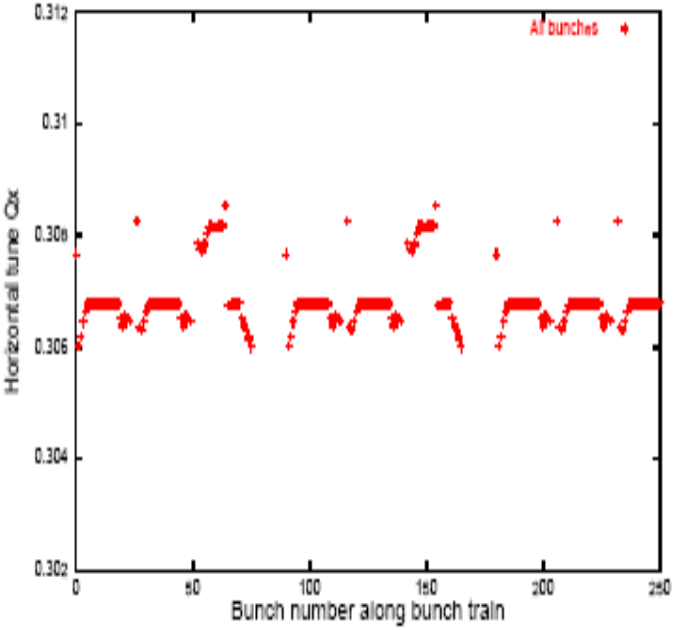


Figure 10: Tune variation along bunch train, new scheme with 75 ns spacing. Two crossings.

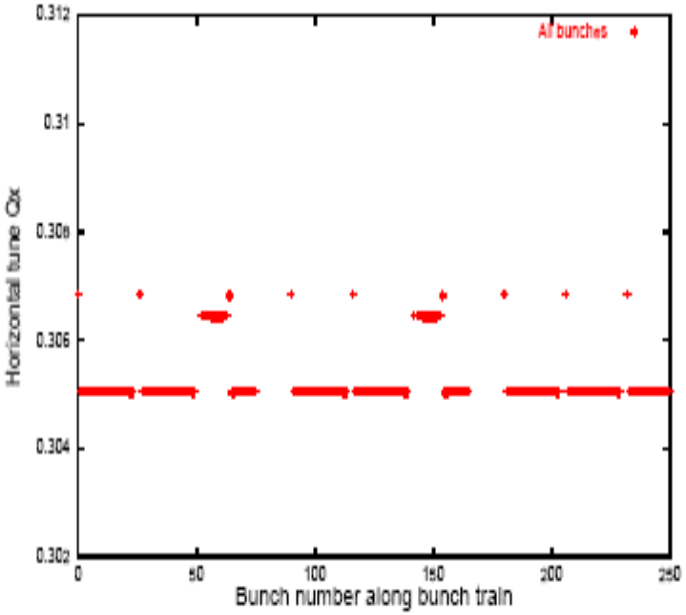


Figure 11: Tune variation along bunch train, new scheme with 75 ns spacing. Alternating crossings.

From LHC Project Note 321, W. Herr (2003)

CERN tune specs

LHC Project Document No.

LHC-B-ES-0009 rev 1.0

5. EXPECTED TOLERANCES ON THE OBSERVABLES/PARAMETERS

The analysis of the expected tolerances of the beam dynamics to variations in the beam parameters is done to identify the requirements on accuracy for the instruments.

5.1 TUNE AND TUNE SPREAD

Tracking studies at injection (LHV v6.0, [15]) show that the LHC working point is located almost at the centre of a stability island with a width corresponding to $\Delta Q = \pm 0.010$. The tolerance on the tunes can be deduced from this observation, after subtracting tune spreads and modulations [12, section 2.3.2]: $2\ 10^{-3}$ for the amplitude detuning, $2\ 10^{-3}$ for the chromo-geometric detuning $2\ 10^{-3}$ for the linear part of the chromatic tune modulation and $1\ 10^{-3}$ for the non-linear part. This leaves a tolerance $\Delta Q = \pm\ 3\ 10^{-3}$ for the adjustment of the central betatron tunes at injection.

In collision, the machine operates closer to the diagonal with a tune split of $Q_y - Q_x = 0.01$, which corresponds roughly to the tune spread induced by the beam-beam effects. A safe operation of the LHC in collision requests a control of the betatron tunes with an accuracy better than $\Delta Q = 0.001$, i.e. better than 10% of the tune separation.

Several mechanisms may induce a tune spread amongst the bunches:

- The electron cloud produces a tune shift which depends on the bunch position in a batch. A tune shift of the order 0.005-0.01 along a train has been observed at KEKB and in the SPS [16] and should be expected during the beam scrubbing.
- The Pacman effect induces a beam-beam linear tune shift which depends on the beam position. Its value is 0.001 for the nominal alternate crossing and might reach 0.003 if other crossing schemes remain possible [8].

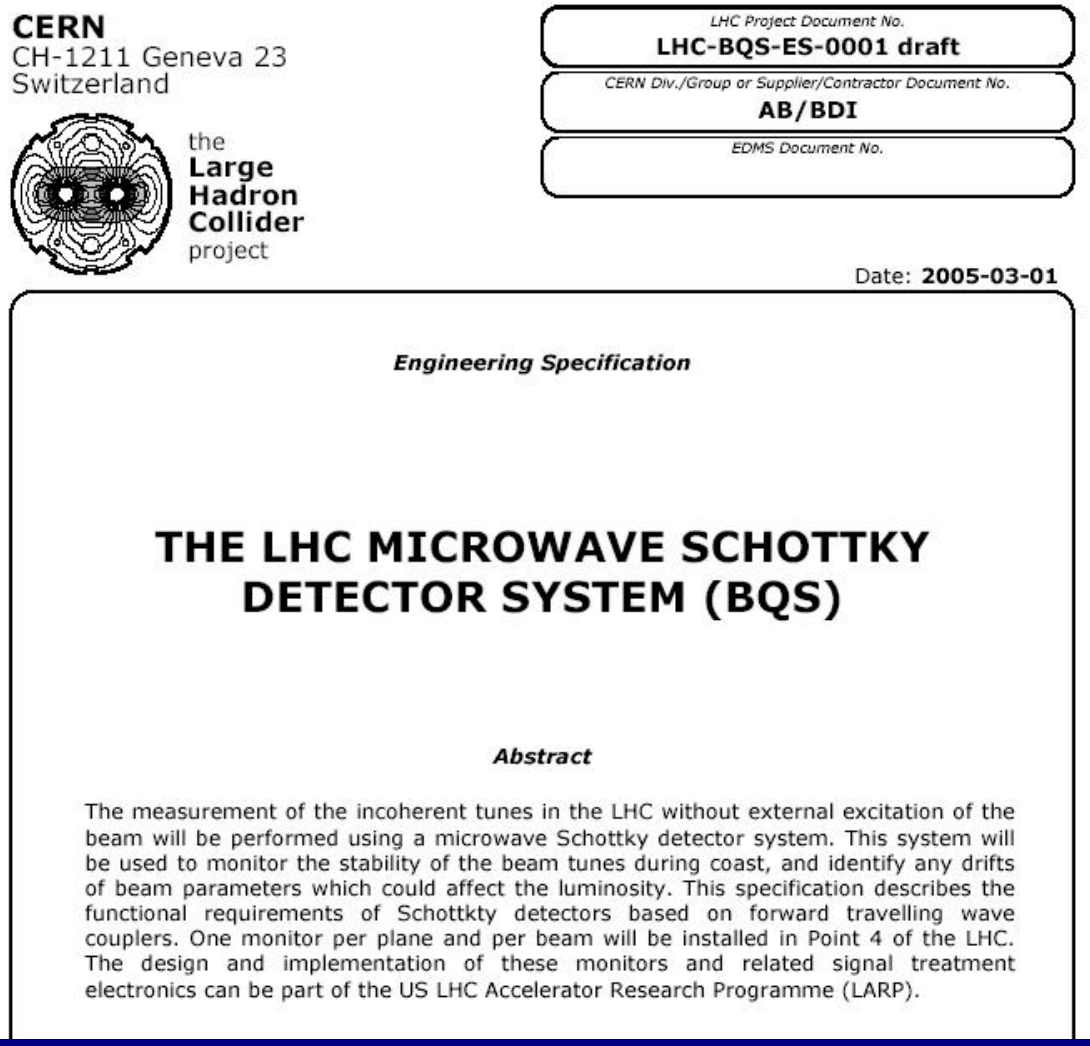
12.6 BUNCH SELECTIVITY FOR THE MEASUREMENTS

In most cases, the beam average of the tunes, chromaticities,... are appropriate. This mode should be considered as the priority mode of operation for LHC in terms of availability and accuracy The identification of the e-cloud effect would benefit from a bunch-by-bunch measurement of the tunes. When the machine performance reaches the nominal level, a bunch by bunch measurement of the tunes and possibly of chromaticity is likely to become necessary. The measurement of the amplitude detuning and of the beam-beam transfer function requires as well a bunch-by-bunch measurement. The bunch-by-bunch mode is thus demanded to be available from the beginning as a commissioning tool, whether or not the precision targets are initially reached

- Microwave Schottky provides passive bunch-by-bunch tune measurement (and more).
- CERN is specifically requesting this from the start!
- Only tune measurement foreseen in store mode!
- **No other non-destructive instrument planned with single bunch capability!**

Schottky specification

- Schottky is part of the LHC baseline (but not the experience to implement it)!
- Schottky specification now exists!
- We can meet the spec.



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EDMS Document No.

Date: **2005-03-01**

Engineering Specification

THE LHC MICROWAVE SCHOTTKY DETECTOR SYSTEM (BQS)

Abstract

The measurement of the incoherent tunes in the LHC without external excitation of the beam will be performed using a microwave Schottky detector system. This system will be used to monitor the stability of the beam tunes during coast, and identify any drifts of beam parameters which could affect the luminosity. This specification describes the functional requirements of Schottkty detectors based on forward travelling wave couplers. One monitor per plane and per beam will be installed in Point 4 of the LHC. The design and implementation of these monitors and related signal treatment electronics can be part of the US LHC Accelerator Research Programme (LARP).

LARP project criteria

- ☑ Luminosity
  - Will help understand the machine, and hence increase luminosity.
- ☑ Commissioning –
  - Requires US-LARP people on location to commission devices.
- ☑ R&D
  - Some technical challenges in e.g. chromaticity, ramp.
  - We are still trying to understand bunched beam Schottky signals in the Tevatron.
  - Several beam physics studies requires bunch-by-bunch measurement of e.g. tunes and emittances (beam-beam, pacman, e-cloud).

Deliverables/Milestones

- A study of performance limitations in terms of S/N for low intensity bunches using the 1.7 GHz Schottky system installed in the Tevatron. **(FNAL, FY'06)**
- Design of a traveling wave pick-up structure optimized for the LHC beam and machine parameters. CERN pays for the manufacturing **.(FNAL, FY'06)**
- Design and assembly of four sets of front-end electronics (plus spares) for the pick-ups. This includes all amplifiers, filters, gating and down-mixing circuitry between the pick-ups and the digitizer. CERN provides the gate generator (TTL level), a 40 MHz RF source and the DAQ hardware **(FNAL, FY'06-07)**
- A study of the performance of the DAB board (with 24 bit, 96 kHz ADC mezzanine card) for 1.7 GHz Schottky signals in RHIC and/or Tevatron. **(BNL/FNAL, FY'06)**
- Porting the Fermilab Schottky analysis software to the CERN control system framework. CERN provides the generic controls communications software and the platform for running the code. **(FNAL, FY'06-07)**
- Hardware commissioning with US personnel on location at CERN. This includes transferring expertise to a local CERN designee. **(FNAL, FY'07-08)**
- Beam studies on location at CERN to attempt to e.g. passively measure tunes during ramp and squeeze (this has been difficult in the Tevatron, but may be possible in the LHC due to the much slower ramping). Also attempt emittance and chromaticity measurement**. (FNAL, FY'07-08)**

- Capability to continuously measure the average LHC tune during stores without external excitation. This has shown very useful in the Tevatron, and allows for slow tune feedback during stores, if required. (**FY'07-08)**
- Capability to measure tune of user-selected single bunches in the LHC. Studies of e.g. electron cloud effects and beam-beam detuning of single bunches (PACMAN effect), which are expected to be critical to the LHC performance, will rely on this capability. **(FY'07-08)**

Budget estimate

	FTE years	M&S
Design PU structure	5/12	
Design & build electronics	3/12	$25k
DAQ study (BNL+FNAL)	2/12	
Port software	3/12	
Installation and commissioning	2/12	travel*

*Two short trips to CERN, plus one longer trip for commissioning for two people each time

People

- FNAL
  - R.Pasquinelli, P.Lebrun , D.Sun, D.Tinsley, A.Jansson
- BNL
  - P.Cameron, P.Oddo
- CERN
  - F.Caspers, R.Jones

Conclusions

- Schottky would be the only tune measurement during store!
- Bunch-by-bunch useful for beam physics (interest from eg T.Sen, JP.Koutchuk, F.Zimmerman)
- It is relatively inexpensive (~1FTE year +$25k+travel)
- Connection to AP task?